Exhibit A

Upgrading Nine Concord Avenue/Garden St Signals to MBTA's NextGen TSP

Contents

1.0 Executive Summary

The MBTA, in partnership with local traffic signal owner-operating agencies, operates a Transit Signal Priority (TSP) system to improve the on-time performance and operational efficiency of the transit system.[1] The MBTA bus/light rail fleet are equipped with onboard communications and GPS location technology that provides location and status information. The signal systems are expected to obtain this information from MBTA's existing Automated Vehicle Location (AVL) system and provide TSP.[2]

The Next Generation of Transit Signal Priority and Signal Performance Measures Technical Specification is intended to serve as guidance to local agencies when procuring traffic signal control hardware and software to meet current best in class functionality including the specialized needs of the MBTA. It will also address improving accuracy of 'stop bar' arrival predictions, which significantly impacts TSP effectiveness; enabling the collection of high-resolution data for each intersection, allowing for more robust evaluation of the TSP system as a whole; and providing a suite of technologies at varying levels of technological capabilities and cost. As a benefit for the local agency, the high-resolution signal data collected by the Advanced Transportation Controllers (ATC) can be processed into Signal Performance Measures (SPMs) and then be used to optimize signal operations without the need for time consuming and expensive traffic studies.

1.1 MBTA TSP Operations

TSP operates as follows:

- The MBTA uses AVL to track bus locations on a continuous basis. MBTA makes this location information available in real-time through their publicly available API at www.mbta.com/developers.
- The priority request generator (PRG) identifies a bus approaching a signalized intersection.
- A priority request is created for each active in-service bus on the route and sent to the priority request server.
- Once received, a call is placed into the controller to request priority. There are several priority treatments that can reduce the time it takes the bus to move through the intersection. The two most common are extended green or shortened red. The decision to grant priority along with the type of treatment and the logic to recover to normal operations is all determined by the rules within the ATC.
- When the bus leaves the intersection, the priority request generator triggers the call to be dropped and the signal returns to normal operation.

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[1] These specifications focus on buses, but also apply to Green Line trolleys, which are within the purview of TSP when traveling through mixed-traffic intersections.

[2] These specifications do not apply to for example the signals connected to the City of Boston's Traffic Management Center.

The ATC collects and logs data including traffic volumes (from the intersection detectors), pedestrian pushbutton activity, signal phasing, TSP calls, and other controller functions every tenth of a second. This data is periodically sent to the local Agency and/or MBTA API for processing into T-SPMs.

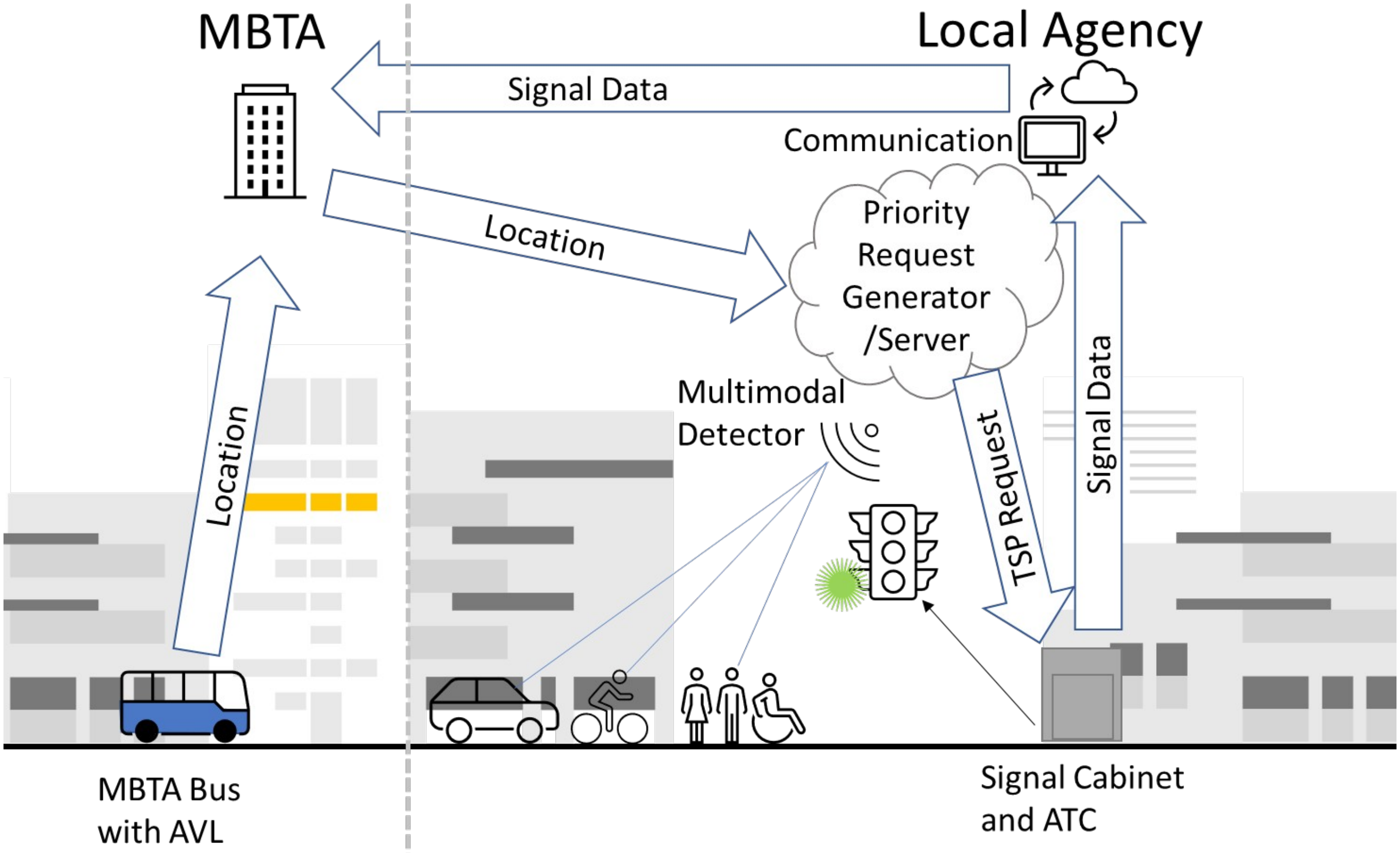

Figure 1 Transit Signal Priority Operational Diagram

The system components included in this specification includes:

1. **Controller:** The traffic signal controller is the piece of equipment in the signal cabinet that translates input from detectors into the displays that are detected on the street. Signal timing parameters are programmed into the controller software to determine the allocation of green time and interpreting detector and display information.

2. **Priority Request Generator (PRG)/Priority Request Server (PRS):** The PRG and PRS are functional entities that work together to provide the necessary services needed to request TSP. In the case of MBTA, the PRG would receive active in-service bus AVL data on a continuous and real-time basis directly via the MBTA API. The PRS receives these data and translates them into the actual detector cabinet and/or controller inputs assigned to that function based on controller configuration. The PRS may perform additional filtering and logic functions based on local agency policy that may

determine if and when a request is made. The MBTA uses unconditional TSP for every intersection therefore additional logic is not anticipated. The local traffic signal controller then determines if and how to adjust timings to support a priority movement for the bus based on a pre-defined TSP timing configuration. The controller determines issues such as reconciling simultaneous requests from different buses for competing priorities or lock out times that limit how often priority may be requested within a given time period.

The architecture and implementation details of the PRG/PRS may vary greatly depending on selected solution and agency equipment capabilities. Both a center-to-field (C2F) and center-to-center (C2C) architectural model are possible to implement TSP within the MBTA operational region. With C2F, the PRG may be either on-premise or cloud hosted. The PRG would communicate directly to a PRS in each field traffic signal controller cabinet thereby bypassing any central traffic signal management capability. In this scenario a PRS device in each cabinet would receive the information and place a priority call into the controller. This would most likely be the case in situations where the local traffic signal owner-operating agency does not have a central traffic signal management system with full-time communications to each traffic signal cabinet. With C2C, the MBTA server communicates the AVL messages directly to the traffic signal owner-operating agency centralized traffic management system. The centralized traffic management system would include the PRG functionality and would use the same communications path supported by other centralized traffic operations to also issue the TSP request to the traffic signal controller. The PRS function may reside centrally alongside the PRG or may be distributed to each traffic signal cabinet depending upon implementation details.

3. **Communications and Reporting:** The MBTA’s goal of signal communications is twofold; to provide TSP for transit vehicles moving through a signalized intersection, and to retrieve the hi-resolution data from traffic signal controllers to analyze and understand operational performance.

   The MBTA has completed an effort to standardize transit detection setup so that this can be used with the ATSPM enumeration to produce Transit focused Signal Performance Measures (SPM). This data is typically stored in a circular buffer on each traffic signal controller. Each controller event is time stamped and stored in a first-in/first-out buffer that will begin to automatically overwrite the oldest events once the buffer is full. The number of recorded events over a given period is dependent upon the intersection complexity and traffic volumes.

2.0 Introduction and Overview

The Massachusetts Bay Transportation Authority (MBTA) is looking to upgrade 9 traffic signals to MBTA's next generation TSP specifications. The vendor will ensure that the following criteria are met:

1. Traffic controller needs to have data recording based on NTCIP 1211 standards as defined in the Indiana Traffic Signal Hi Resolution Data Logger Enumerations (where required, as defined in the project scope below). Technical Specifications are defined in Section 3.1 "Controller Specifications"
2. Traffic controller needs to adhere to the MBTA's data logging standards as defined in MBTA's Virtual Bus Detector Methodology, Section 4.0.
3. Traffic controller needs to adhere to the "Communications and Reporting" specifications as described in section 3.3
4. Priority Request Generator needs to adhere to latest specifications as described in the Priority Request Generator/Priority Request Server (PRG/PRS) and "Communications and Reporting", described in sections 3.2 and 3.3, respectively.

2.1 Intersection Locations

All intersections are in Cambridge, MA

- Concord Avenue & Blanchard Road
- Concord Avenue & Moulton Street
- Concord Avenue & Alpine Street
- Concord Avenue & Walden Street
- Concord Avenue & Huron Avenue
- Concord Avenue & Craigie Street
- Garden Street & Concord Avenue
- Garden Street & Mason Street
- Garden Street & Appian Way

* Return all unused TSP and signal equipment not needed for upgraded signal work to their respective municipalities.

3.0 System Components

The system components below provide for the performance standards required for a new or upgraded system to facilitate the continued MBTA TSP operation and collection and reporting of standard compliant hi-resolution traffic data that is required to calculate Signal Performance Measures to MBTA. It also provides the capability to improve ETA predictions over time. The vendor will ensure that the following criteria are met:

3.1 Controllers

To provide the data needed for T-SPMs a NEMA standard ATC Controller with hi-resolution data logger is required. The data logger collects signal controller status on a 1/10th of a second interval. The data is defined and formatted in accordance with the Indiana Traffic Signal Hi Resolution Data Logger Enumerations [3](August 2020 or latest version.) This document defines the enumerations, events, parameters, and descriptions of all hi-resolution data to be recorded on the traffic controller and forms the basis for calculating Signal Performance Measures.

- **TS2-2016** Traffic Controller Assemblies with NTCIP Requirements Version 03.07 is the latest NEMA Traffic Signal Controller standard that provides a functional, mechanical, and electrical interface definition for the Field I/O connectors of the traffic controller. It provides cabinet level interchangeability but does not define nor support controller hardware or application software interchangeability. A controller from one vendor can be easily swapped with another vendor controller within the same NEMA TS2 cabinet, but controller component hardware and application software remain proprietary to the vendor. The TS2 standard utilizes a Synchronous Data Link Control (SDLC) serial communication Field I/O bus to communicate with cabinet devices.
- **NTCIP 1202 v2** (Actuated Signal Controller object definition) **with the Indiana Traffic Signal Hi-Resolution Data Logger Enumerations** (defined in NTCIP 1202 v3) and allows for operational data to be retrieved from the controller. The following events are Mandatory [M], Strongly Recommended [SR], and Desired [D] to be in the high-resolution log.

  i. [M] Phase Begin Green

  ii. [M] Phase Begin Yellow Clearance

  iii. [M] Phase End Yellow Clearance

  iv. [M] Detector Check-in (for TSP virtual detectors, defined in the MBTA TSP detection guidance)

  v. [M] Detector Check-out (for TSP virtual detectors, defined in the MBTA TSP detection guidance)

[3] Li, Howell & Hainen, Alexander & Sturdevant, James & Talukder, Md Abu Sufian & Mathew, Jijo & Bullock, Darcy & Nelson, Daniel & Maas, Donald. (2019). Indiana Traffic Signal Hi Resolution Data Logger Enumerations. 10.5703/1288284316998.

vi. [M] TSP Check-in

vii. [M] TSP Check-out

viii. [M] TSP Types (Early Return, Green Extension, etc.)

ix. [M] TSP denied reason

x. [M] Priority Parameter (Time of Service Desired, Priority Class, Transparity Parameter, etc.)

xi. [SR] Detector Check-in (other)

xii. [SR] Detector Check-out (other)

xiii. [SR] Phase Gap Out

xiv. [SR] Phase Max Out

xv. [SR] Phase Force Off

xvi. [D] Other event listed in the Indiana Traffic Signal Hi Resolution Data Logger Enumerations

- **The NTCIP 1211** Object Definitions for Signal Control and Prioritization (SCP) standard defines the application layer data to be exchanged to support bus or rail transit signal priority (TSP). The NTCIP 1211 SCP Concept of Operations is comprised of two primary elements, the Priority Request Generator (PRG) and a Priority Request Server (PRS). A transit vehicle, which could be a light rail train, bus, or other transit vehicle, through its agent, the PRG, submits a request for priority to the PRS. These two elements can be thought of as a logical process that could be physically implemented in more than one way. The specific hardware implementation details are not defined here but left to the local agency and MBTA to determine. The standardization occurs at the interface of these processes and represents the objects developed by NTCIP 1211. The two primary interfaces are (1) between PRG and PRS and (2) between PRS and the traffic signal controller coordinator, which implements special coordination operation.

  ATC 5201 v06.34 standard defines a minimum required functional capability of hardware and software for an on-street transportation controller computing platform. A key component of the standard is the Engine Board which contains all of the computational facilities. Standardized edge connectors define how this board mates with the receiving Host Module of the controller platform. While the Engine Board is completely specified, the Host Module and the rest of the controller platform may be of various shapes and sizes based on vendor preference. The intention is to allow portability of the Engine Board to accommodate upgrades with technology advances or cross vendor deployment. The standard defines minimum physical interfaces to ensure compatibility with all major transportation field cabinets.

3.2 Priority Request Generator (PRG) / Priority Request Server (PRS)

i. The PRG should be capable of ingesting AVL data, providing simple trip wire check-in/check-out detection based on virtual detector locations, and evaluating each received AVL record to determine the bus location relative to

the TSP detector locations.

ii. The PRG needs to have a map of the agency intersections, intersection names and numbers, and accurate geospatial information about each intersection TSP detectors (check-in, and check-out) for all bus routes and approaches.

   - The TSP virtual detectors shall be programed based on the MBTA TSP detection guidance, “Virtual Bus Detector Methodology,” section

3.3 Communications and Reporting

The MBTA's goal of signal communications is twofold; to provide TSP for transit vehicles moving through a signalized intersection, and to retrieve the hi-resolution data from traffic signal controllers to analyze and understand operational performance.

i. Either modem to connect signal to cloud and receive priority and preemption requests, or central signal system with active link to signals and connected to the cloud.
ii. All communications need to be compliant with national standard (NTCIP)
iii. All communications to support this capability need to conform to Internet Protocol (IP) broadband standards.
iv. For the TSP systems to operate properly, hardware must be capable of supporting continuous full-time IP communications.
v. Depending upon the local agency architecture, the communications can either be dedicated to the TSP function or be combined with other signal management functions onto a single communication channel.

To support TSP operation, the traffic signal owner-operating agency needs to have a centralized PRG process capable of connecting to the MBTA's API. This connection enables reception of continuous and real-time bus location data.

i. An Internet-based virtual private network (VPN) broadband connection (typically 1-15Mb/s) with MBTA is preferred.
ii. A single PRG process and VPN-based API connection is preferred to manage this interface more efficiently.
iii. TSP communications between the PRG/PRS and each local traffic signal controller requires minimal bandwidth (typically <1Mb/s).
iv. Low latency performance is required for each connection to ensure timely reception and processing of TSP requests.

To support hi-resolution data reporting, the traffic signal owner-operating agency needs a centralized file server capable of connecting to the MBTA API to report back hi-resolution data collected and stored on the traffic signal controller.

i. A single Internet-based VPN API connection (typically 1-15Mb/s) is preferred.
ii. This connection may be shared with the PRG.
iii. Communications between the central file server and each local traffic signal controller requires minimal bandwidth (typically <1Mb/s).
iv. Either FTP or API can be used to report the data. Both need to account for the possibility of duplication due to the nature of the controller circular buffer. The vendor API need to be compatible with MBTA system to allow data reporting. The MBTA Customer Technology Department (CTD) team shall provide the specifications on the API details.
v. To avoid conflict, it is recommended that only a single central system for each agency be responsible for collecting and storing the data from each controller and then making it available to all other users including the MBTA.
vi. The upload frequency of the data from each controller shall be an hour or at maximum upload frequency and storage capacity shall be sufficient for a

year worth of data.

vii. **Security**. All data and access to data stored on the controller shall be password protected and secure.

viii. **Data recording**. See Section 4.0 Virtual Bus Detector Methodology on how transit location data is to be recorded within the controller data logger.

ix. **Data Transfer.** All Signal Controller Data shall be transmitted hourly to MBTA's Amazon Web Services (AWS) S3 bucket "cloud storage". If vendor utilizes Amazon AWS, MBTA will provide cross account access. If vendor does not utilize Amazon AWS, MBTA will provide the access key and secret key to storage. Any data written in a proprietary format must be decoded by the vendor to convert the data to a comma separated values file type (CSV). This decoding can either occur prior or after submitting the data to the MBTA's "cloud storage" but it is the vendor's responsibility that this data has been converted to the CSV regardless of where in the process this conversion occurs.

x. **Troubleshooting**. If the data is not transmitting properly which could be due to a number of factors including but not limited to: internet or power outages at the traffic signal, data corruption issues, file transfer issues or software credentialing issues the vendor shall make a reasonable and timely effort to troubleshoot and resolve the issue within 3 business days.

xi. **Years of Service and Renewing**. It is expected that the vendor will provide signal data for 3 years from installation. If vendor is no longer doing business, vendor shall provide reasonable accommodation to transfer product and software to MBTA and/or municipality.

xii. Unless otherwise specified, all internet communication to/from the signal controller and its component parts shall be in operation for 15 years.

4.0 Virtual Bus Detector Methodology

The purpose of this memorandum is to establish a regionally consistent way to define detectors to locate buses with respect to a signalized intersection for high-resolution signal controller data. The vendor will ensure that the following criteria are met:

Background

To provide Transit Signal Priority (TSP) at a signalized intersection, an arriving bus is first detected with an upstream detector and a request is made to the signal controller to prioritize the bus movement through the signal. To measure the effectiveness of TSP, high-resolution signal controller data is utilized to track changes to signal phasing and timing, bus arrivals, and delays.

Within the MBTA service area, each municipality installs, operates, and maintains its signal controllers in its jurisdiction, using various signal controller manufacturers, operating infrastructure, and communication infrastructure. However, each TSP vendor must detect an MBTA transit vehicle via our publicly available API. [4]

MBTA is in the process of developing a dashboard to capture transit-specific performance metrics at TSP-enabled intersections utilizing high-resolution signal controller data. To enable this, MBTA is developing specifications to standardize TSP functionality, detector placement, reporting of metrics, and high-resolution data formats.

This memo addresses the detector placements of typical intersection layouts to demonstrate how to locate a bus arrival upstream of an approach and track the bus location as it traverses the intersection. The bus-specific detector calls are logged into the high-resolution data files, which are then processed to generate TSP-specific performance metrics.

Detector Lengths

Bus detectors should be sized to capture the necessary number of GPS pings from a bus. The recommended detector length can be calculated based on the formula below:

$$L = v \times (n+1) \times f \times 1.467$$

Where:

L= recommended detector length (ft), rounded up to the nearest 50

v= average bus travel speed (mph)

n= minimum number of pings needed to geolocate the bus and the direction of travel

f= bus ping frequency (sec)

For example, if a bus travels at an average speed of 20 mph, pings every 6 seconds and the geolocator system needs two pings to locate the buses, then the

[4] http://www.mbta.com/developers

recommended detector length is 20 * (2+1) * 6 *1.467 ~ 550 ft.

Detector Placement

For each intersection approach, when possible, place 3 virtual ‘geofence’ detectors at each approach one ½ mile upstream, one ¼ mile upstream and one L (recommended length) feet to the stop bar. Additionally, place one virtual ‘geofence’ detector as a check-out on the departure approach. When this is not feasible due to upstream signalized intersections, adjust accordingly by placing the furthest upstream detector immediately downstream of the next upstream signal. All upstream detector boundaries shall start at the aforementioned locations enabling the bus to trigger the detector. For the detector at ½ mile upstream, the detector shall begin at ½ mile upstream and shall be the calculated length downstream.

Detector Event Parameter Values

The purpose of the event parameter values is to identify the bus approach and movement with respect to the signalized intersection. Each virtual ‘geofence’ detector is assigned a unique parameter value of event codes 82 detector-on and 81 detector-off as defined in the Indiana Traffic Signal Hi Resolution Data Logger Enumerations[5] that can be mapped to the intersection. Given that each intersection is unique and could have multiple configurations, a consistent way to number parameters of detector events is necessary.

Using the approach that is closest to the cardinal north direction, detector parameters can be numbered starting from 50 for the upstream check-in detector and sequentially numbering them until the check-out detector. The numbering continues on the next approach in the clockwise direction and sequentially numbering them from the upstream check-in to the check-out.

For example, if an intersection has four legs, and the approach that is closest to cardinal north has four detectors: a check-in, an update, a stop-bar and a check-out detector, they would be numbered 48, 49, 50, and 51 respectively.

Detector configurations for typical intersection layouts

Figures 1,2 and 3 show the configuration of a typical 4-legged, 3-legged and 5-legged intersection respectively.

[5] https://docs.lib.purdue.edu/cgi/viewcontent.cgi?article=1003&context=jtrpdata

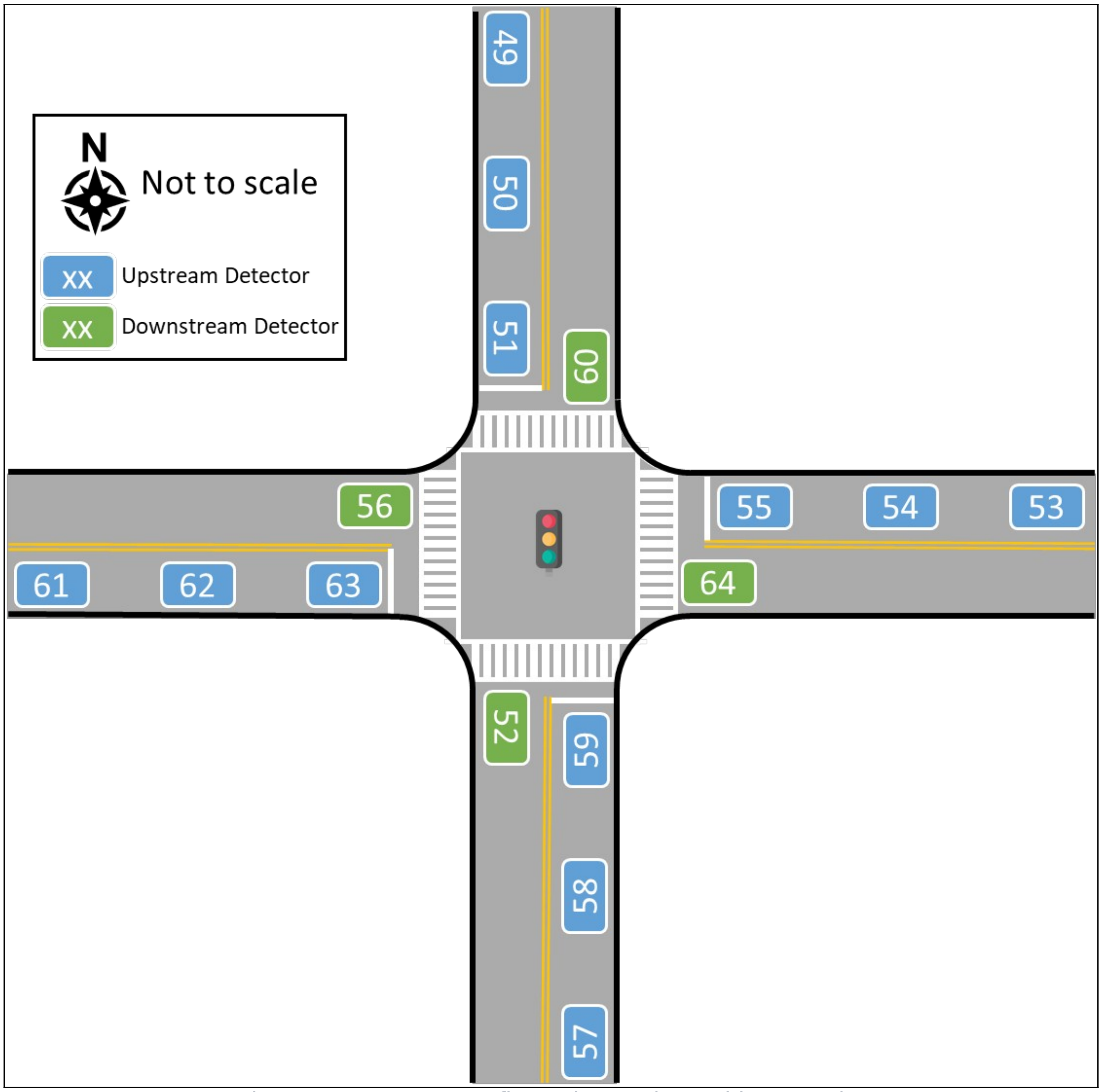

Figure 2: Detector Configuration - 4-legged intersection

As mentioned previously, the approach that is closest to cardinal north (southbound approach) has three upstream detectors and a downstream check-out detector, they shall be numbered 49 through 52. Next, working clockwise through the approaches, the westbound approach shall be numbered 53 through 56, the northbound approach shall be numbered 57 through 60 and the eastbound approach shall be numbered 61 through 64.

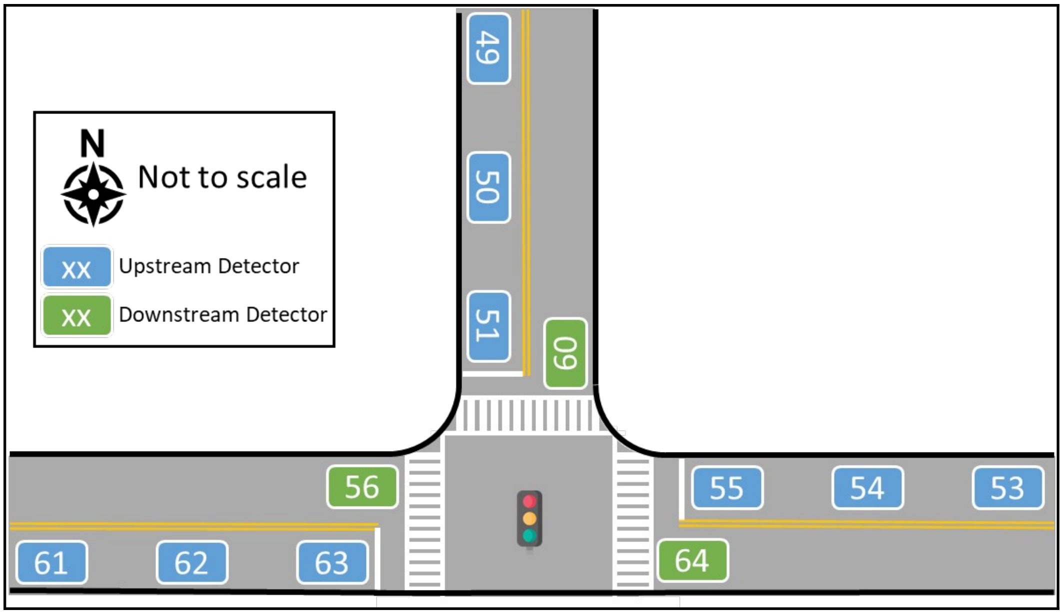

Figure 3-1: Detector Configuration - 3-legged intersection

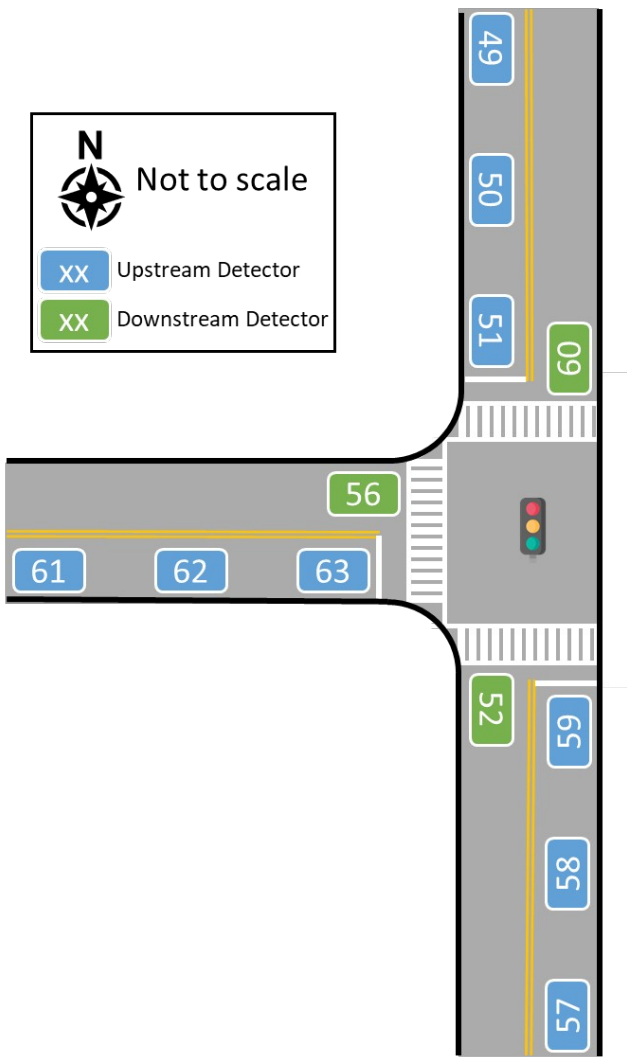

Figure 4-2: Detector Configuration - 3-legged intersection

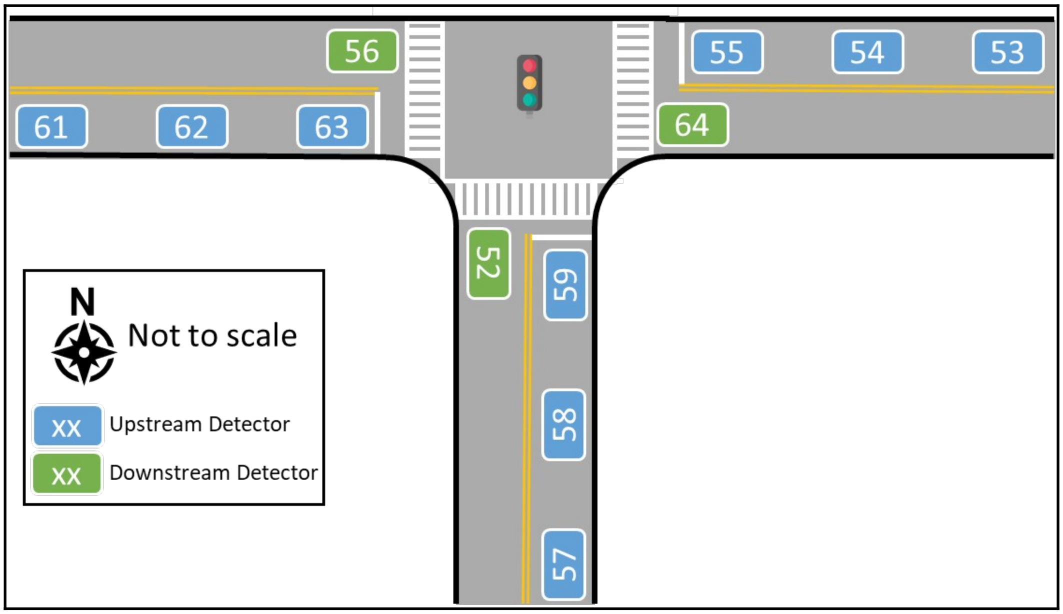

Figure 5-3: Detector Configuration - 3-legged intersection

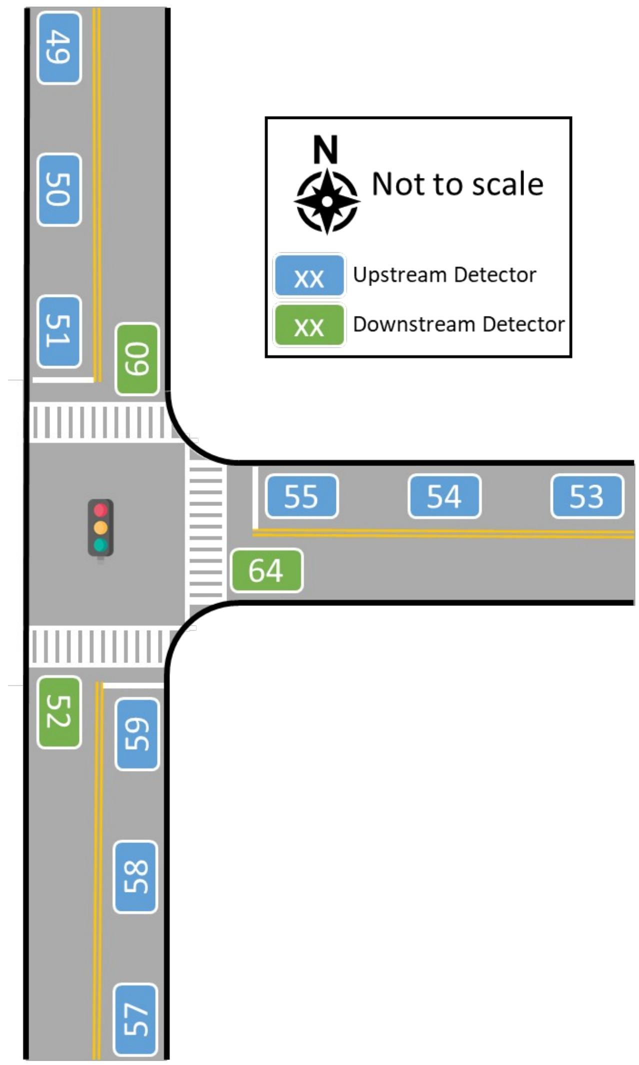

Figure 6-4: Detector Configuration - 3-legged intersection

A three-legged intersection shall be numbered like a 4-legged intersection but skipping the numbers for the absent leg. Take Figure 2-4 as example, the approach that is closest to cardinal north (southbound approach) has three upstream detectors, and a downstream check-out detector, they shall be numbered 49 through 52. Next, working clockwise through the approaches, the westbound approach check-in detectors shall be numbered 53 through 55 but 56 for check-out detector shall be skipped since there's no receiving lane on the west side. The northbound approach shall be numbered 57 through 60. The eastbound approach check in detectors shall be skipped since there is no eastbound approach and the check-out detector shall be numbered 64.

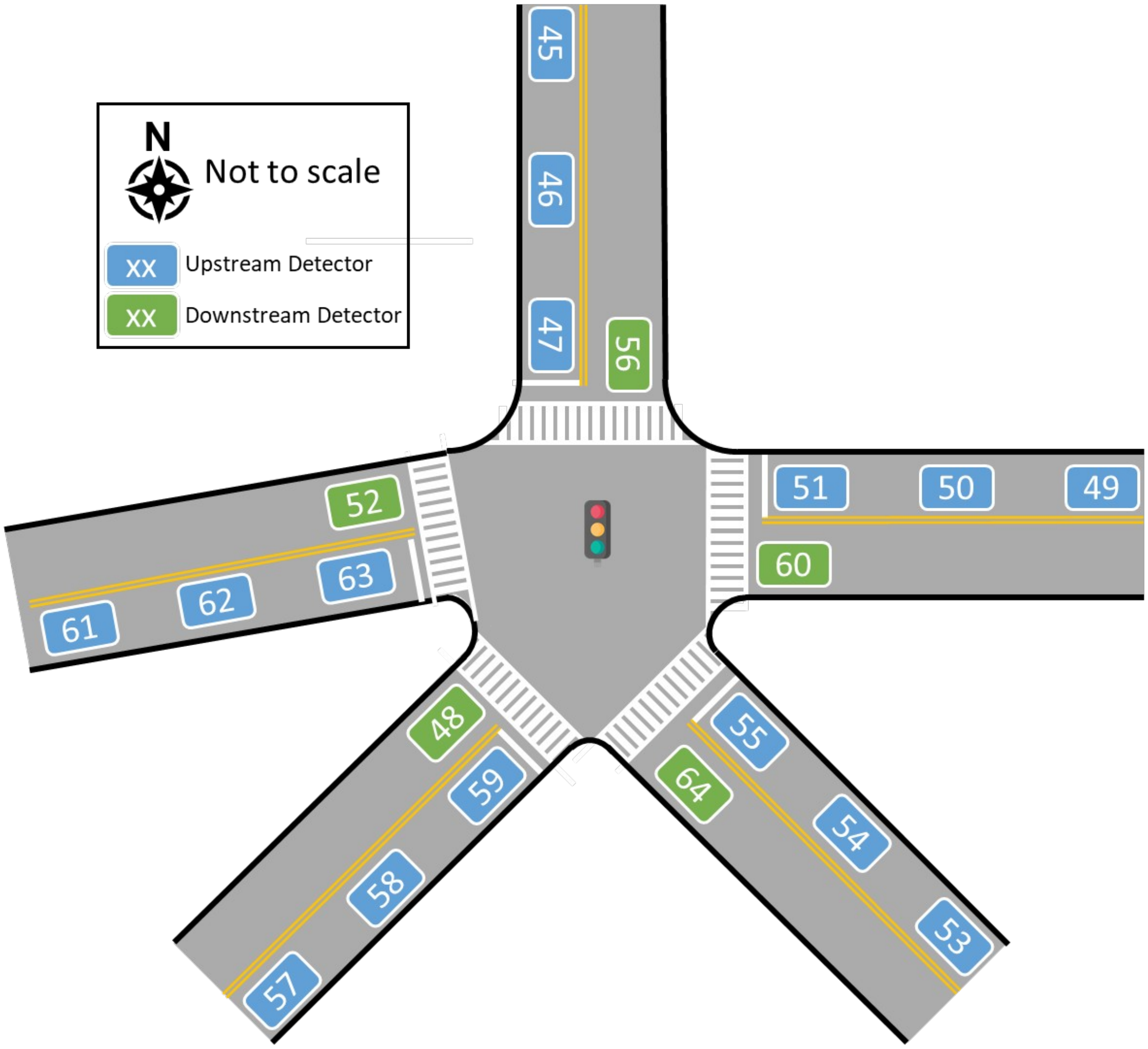

Figure 7: Detector Configuration - 5-legged intersection

For a five-legged intersection, the approach that is closest to cardinal north has three upstream detectors and shall be numbered 45 through 48. Other approaches shall be numbered going clockwise as shown in the above figure.

NOTE: For intersections that are more than four-legged but only have bus service on four or less legs, numbering shall be the same as the four or three-legged intersections. This way for bus service in the same cardinal direction along a corridor all detector zones will be numbered identically as the bus passes from intersection to intersection along a corridor.

5.0 Glossary of Abbreviations

ATC: Advanced Transportation Controllers

ATSPM or ATSPMs: Automated Traffic Signal Performance Metrics

AVL: Automated Vehicle Location

C2C: Center to Center

C2F: Center to Field

ETA: Estimated Time of Arrival

GPS: Global Positioning System

GTFS: General Transit Feed Specification

IFB: Invitations For Bids

ITS: Intelligent Transportation Systems

M60: Model of signal controller currently owned by Yunex.

MBTA: Massachusetts Bay Transportation Authority

NEMA: National Electrical Manufacturers Association

NTCIP: National Transportation Communications for ITS Protocol

PRG: Priority Request Generator

PRS: Priority Request Server

TSP: Transit Signal Priority